Developing a SPiCT model for assessing pollack stock in the Bay of Biscay and Iberian waters

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Abstract

A stochastic surplus production model (SPiCT) was applied to the Bay of Biscay and Atlantic Iberian waters stock of *Pollachius pollachius*. Based on a previous model presented at the WKMSYSPICT-part1, the catch series was extended to earlier years and the abundance index FR-GNS90-8a-2S was updated with a new year of data. Priors were set for the intrinsic rate of growth (r) and shape parameter (n). A final configuration of the model was stable and provided realistic results. Although the model diagnostics indicated a slight violation of the normality of the residuals, the retrospective pattern was acceptable. The perception of the status of pollack was that relative biomass and fishing mortality were within safe biological limits.

1. Introduction

A preliminary stock assessment for pollack in ICES Area 8 and Division 9a using SPiCT was presented at the WKMSYSPICT-part 1. In order to improve the stability and robustness of the model, the WK suggested extending the time series of landings to earlier years, updating the standardized abundance index with 2019 data, and justifying the priors set for the initial biomass depletion level. The aim of this work is to include the changes proposed during the WKMSYSPICT-part1 and to develop a new model configuration to assess the stock status of pollack.

2. Material and Methods

The data and model configuration is based on the assessment presented in the WKMSYSPICT (November, 2020). The Historical Nominal Catches data set was explored to extract early landings series for the stock (https://www.ices.dk/data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx). A new series of the commercial LPUE FR-GNS90-8a-2s for the period 2005-2019 was standardized following the methodology described in Caill-Milly et al. (2020) and provided to the WK for its use in the assessment.

Stochastic surplus production model in continuous time (SPiCT, Pedersen and Berg, 2017) v 1.3.0 was used to develop an assessment model for pol.27.89a.

3. Results

3.1 Historical landings

In order to include landings records for years before 1986, the ICES historical nominal catches data set was explored for pollack catches. The earlier period with available data for the main countries exploring the stock, France and Spain, was 1979 - 1985 (Table 1). In 1982, Spanish landings were interpolated to obtain a more realistic value. In the case of 1984 and 1985 extremely high values for Spain were observed. Due to the low credibility of these data, the total landings of the stock in 1984 and 1985 will not be considered to be used as input data of the model for Scenarios 1 (Figure 1). For Scenarios 2, the landings series with the extrapolated years (1982, 1999) and the historical values for 1984 and 1985 will be considered, and extra uncertainty will be included for years 1984 and 1985. The largest available landings series covers the years 1979 to 2019. A clear decreasing trend is observed at the beginning of the time series, from 3700 t in 1980 to 1200 t in 1998, and since 2000 landings have fluctuated between 1500 t and 2000 t.

Table 1. Records of commercial landings of pollack in ICES Areas 8 and 9 extracted from ICES Historical Nominal Catches. *estimated value for year 1982. na: not available. **Stock-all records** represent the landings series with the extrapolated values for 1982 and 1999 and the historical landings for year 1984 and 1985, that are considered unrealistic.

Country	**Area/Division**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**
France	8a	2097	1997	2326	2185	2523	2202	2659
France	8b	124	161			129	149	109
France	all	2221	2158	2326	2185	2652	2351	2768
Spain	9				32	203	642	636
Spain	8	1021	1576	902	85	581	1606	2304
Spain	record	1021	1576	902	117	784	2248	2940
Spain	estimated*	1021	1576	902	843	784	na	na
Stock-all records		3242	3734	3228	3028	3436	4599	5708
Stock		3242	3734	3228	3028	3436	na	na

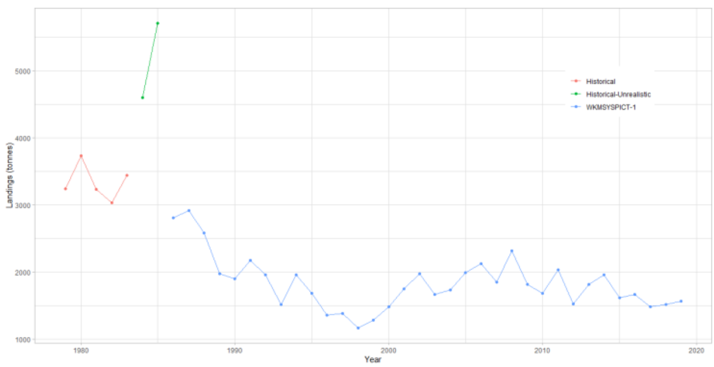

Figure 1. Available commercial landings for pol.27.89a. From 1979 to 1983, estimated landings were derived from ICES historical nominal catches. An interpolation was carried out for year 1982 to estimate Spanish landings and for year 1999 to estimate French landings.

3.2 Commercial LPUE FR-GNS90-8a-2s

The series of the abundance index FR-GNS90-8a-2S was standardized including a new year of data 2019 (Table 2). The updated series includes the period from 2005 to 2019. In this new standardization process slightly different values were obtained compared with the previous series (Figure 2). Both series showed an increasing period from 2005 to a maximum in 2011 following by a decreasing trend until 2018. The updated series of FR-GNS90-8a-2s covering the period 2005-2019 will be included in the assessment model.

Table 2. Standardized LPUE series FR-GNS90-8a-2s updated in 2020.

year	Sum weight (kg)	Fishing sequences (n)	LPUE (kg/fs)
2005	97484	829	118
2006	51794	669	77
2007	120701	895	135
2008	139003	1036	134
2009	104658	810	129
2010	81178	721	113
2011	142528	654	218
2012	149691	746	201
2013	148872	876	170
2014	171901	1045	164
2015	168819	1051	161
2016	147280	1275	116
2017	133351	1151	116
2018	112631	1071	105
2019	164852	1168	141

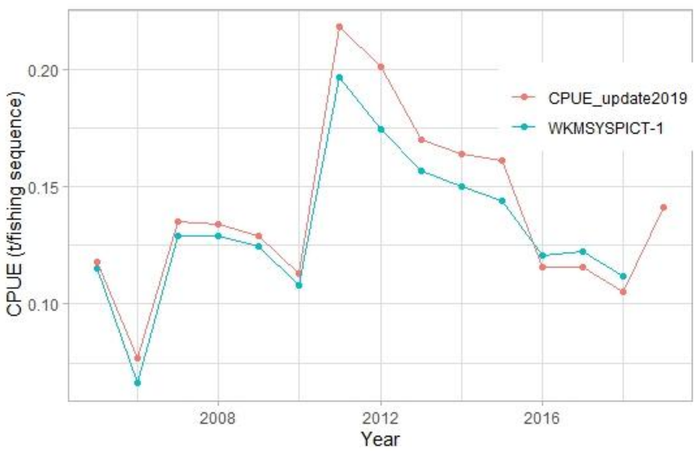

Figure 2. Standardized LPUE index FR-GNS90-8a-2s for the period 2005-2018 (blue) and for the period 2005-2019 (red).

3.3 Justification for priors of initial biomass depletion level (B_0/K)

The preliminary model configuration (WD at WKMSYSPICT-part1) was strongly sensitive to the priors set to the initial biomass depletion level. The convergence of the model was only achieved considering low value of this parameter (logbkfrac <- c (log(0.3),0.5)). Assuming that biomass in the first year of the assessment (1986) was very low derived from an intensive exploitation of the stock.

There are partial records of catches of the stock since 1940's indicating that the fishery started, at least, 80 years ago. However, records of very large catches in the fishery before 1986 were not found and, then, assuming a high depletion of the stock in 1986 is not fully supported.

3.4 SPiCT Model

3.4.1 Input data

The input data includes the time series of commercial landings in tonnes (1979-2019) and one abundance index corresponding with the standardized commercial LPUE FR-GNS90-8a-2s (2005-2019) (Figure 3).

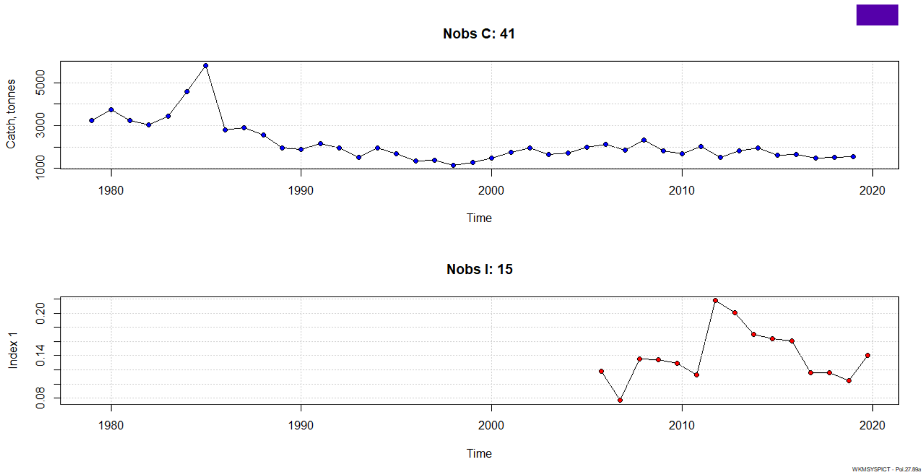

Figure 3. Input data of SPiCT.

3.4.2 Set priors for intrinsic growth rate (r)

The intrinsic rate of population growth (r) is an integrated measure of population resilience and one of the 3 key parameters of a surplus production model. Priors on this parameter were estimated for pollack based on knowledge of historical stock exploitation and the species biology. Priors for r were generated using the R-package SPMpriors (Winker, 2020). First, the r priors were generated from FishLife (Thorson, 2019) using Multivariate-Normal Monte-Carlo simulations based of the species biology information available on FishBase. The stock parameter was translated into surplus production model priors of r, and the MVN parameters were translated into Pella-Tomlinson type parameterization with an age-structured equilibrium approach using the SPMpriors library. The length composition of landings of pollack, available from WGBIE2020, was employed to estimate the length of first capture (Lc) of pol.27.89a. Lc was estimated at 34 cm and was used as input data to calculate the r priors. The Lc is lower than the Lmat (41 cm), and this is related with the fact that the MRCS is set at 30 cm and discards of pollack are considered negligible (< 5% catches) (WGBIE2020). SPMpriors method estimated the following priors for r, mu= 0.23 and log.sd= 0.26.

3.4.3 Set priors for shape parameter (n)

The priors proposed by Thorson et al. (2012) for Gadiformes were used as priors for pollack assessment n.est= 1.729 and sd.n= 0.913. These were set as logn <- c (log(1.729), sqrt(sdn^2 / n.est^2)).

3.4.4 Scenarios

Different configurations of the model were tested. Scenarios are grouped into two sets: Scenario 1.X: input data for landings is the time series of Catch with missing values for 1984 and 1985. Scenario 2.X:

that uses the whole time series of Catch from 1979 to 2019. A summary of the model configuration and diagnostic results for different scenarios are presented in Table 3.

Table 3. Scenarios overview.

	Scenario 1					
Catch data	years: 1979:1983 - 1986:2019					
Index data	years: 2005:2019					
Uncertainty	(1982, 1999) : stdevfacC = 2					
Priors	**Sce1.1**	**Sce1.2**	**Sce1.3**	**Sce1.4**	**Sce1.5**	**Sce1.6**
logn		n=2	n=2	log(1.73), 0.54 (Thorson(2012)	n=2	n=2
logbkfrac			log(0.5, 0.2			
logr				log(1.26), 0.26	log(1.26), 0.26	log(0.23), 0.26
Convergence	X	X	X	X	X	X
Diagnostics				ok, slight normalityC	ok, slight normalityC	
Retrospective				ok, Retro-5 no conv.	ok, Retro -5, -4 no conv.	
Starting values				X	X	

	Scenario 2				
Catch data	years: 1979:2019				
Index data	years: 2005:2019				
Uncertainty	(1984, 1985) : stdevfacC = 5				
Priors	**Sce2.1**	**Sce2.2**	**Sce2.3**	**Sce2.4**	
logn		n=2	n=2	n=2	
logbkfrac			log(0.5), 0.2	log(0.5), 0.2	
logr				log(0.23), 0.26	
Convergence	X	X	X	X	
Diagnostics	X		X	X	
Retrospective	Failed conv.		Inside CI, Mohn's >0.2	Inside CI, Mohn's >0.2	
Starting values			2 local fits	2 local fits	

 # Scenario 1.1. This scenario was configured with the default settings of SPiCT. The model did not achieve the convergence.

 # Scenario 1.2. Default settings of SPICT except for the shape parameter that was fixed at n=2 following a Schaefer approximation. No convergence was obtained.

 # Scenario 1.3. Default settings of SPICT except for the shape parameter that was fixed at n=2and priors for initial biomass depletion were set c(log(0.5), 0.2). No convergence was obtained.

 # Scenario 1.4. The model configuration included setting informative priors for the parameters n and r. Priors for logn were derived from Thorson et al (2012). The priors used for r were: logr <- c(log(1.26), 0.26), assuming a high value of r.

This model achieves the convergence. The estimates of model parameters, reference points and states are shown in Table 4. The production parameter was estimated at 2.01 but its confidence interval was considered very wide (0.96 - 4.2), especially taking into account the priors set for the parameter. The r estimate was 1.14, a high value for this species. The stock biomass in 2019 was above the reference point (B_{2019}/B_{MSY} = 1.32) and the fishing mortality is below the reference point (F_{2019}/F_{MSY} = 0.63) (Figure 4). The production curve does not show any bias. The diagnostics of the model (Figure 5) indicated that there is a slight violation of the normality of the catch residuals (p-value=0.02) being the rest of diagnostics correct. In the retrospective analysis, the “Retro -5” run did not converge. The other 4 Retro runs converged and their estimates of B and F were inside the confidence intervals.

Table 4. Scenario 1.4. Estimates and 95% confidence intervals of model parameters. Reference points and current states.

Model Parameters

	estimate	cilow	ciupp
alpha	0.82	0.22	3.03
beta	1.2	0.24	6.05
r	1.14	0.67	1.95
rc	1.14	0.54	2.41
rold	1.14	0.29	4.5
m	2088	1651	2641
K	7316	4150	12898
q	2.92E-05	1.27E-05	6.66E-05
n	2.01	0.96	4.19
sdb	0.22	0.09	0.56
sdf	0.1	0.03	0.32
sdi	0.18	0.09	0.36
sdc	0.12	0.05	0.28

Reference Points (s)

	estimate	cilow	ciupp
Bmsys	3510	1596	7719
Fmsys	0.56	0.26	1.21
MSYs	1963	1542	2498

States (s)	estimate	cilow	ciupp
B_2019.94	4651	1998	10824
F_2019.94	0.35	0.15	0.84
B_2019.94/Bmsy	1.32	0.87	2.01
F_2019.94/Fmsy	0.63	0.38	1.05

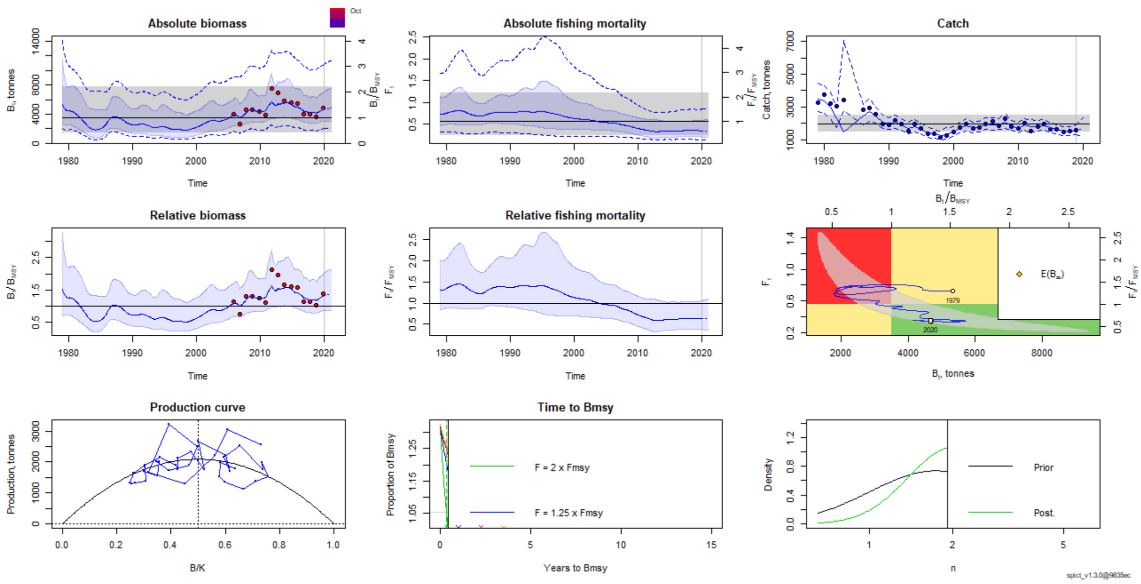

Figure 4. Scenario 1.4. Results of the model fit.

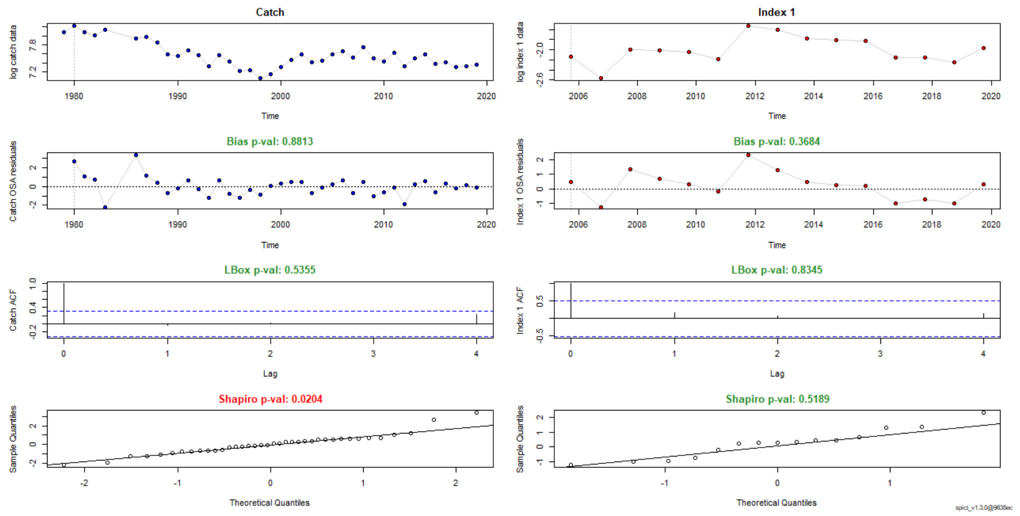

Figure 5. Scenario 1.4. Model diagnostics.

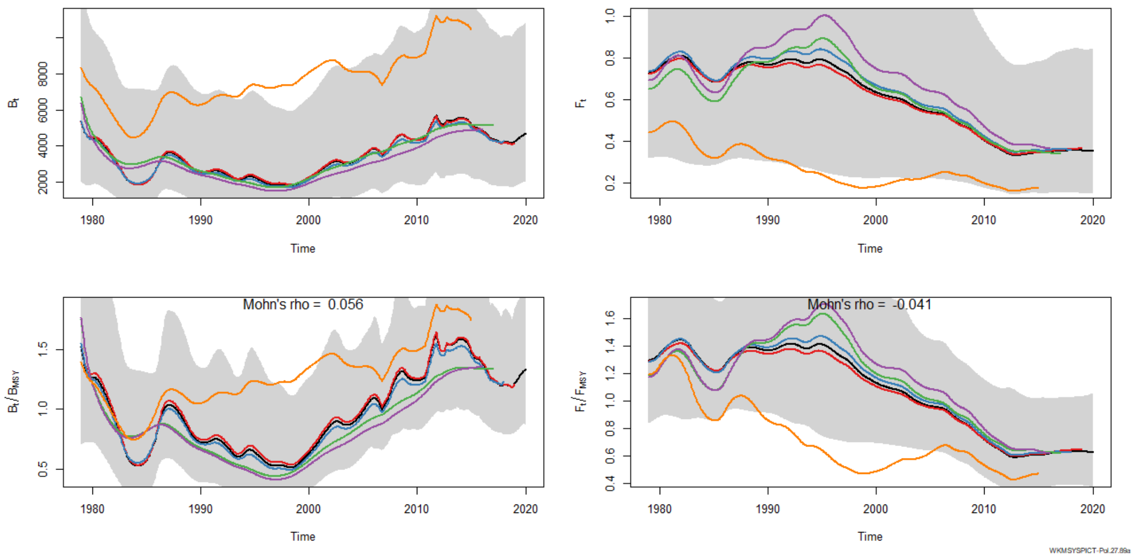

Figure 6. Scenario 1.4. Retrospective analysis. Estimates of biomass and fishing mortality, and their respective relative values, with 95% confidence regions. Mohn's rho number is indicated for relative quantities of biomass and fishing mortality. The run Retro-5 (yellow line) is represented but it did not converge.

 # Scenario 1.5. The configuration of the scenario 1.5 maintains the priors for r from scenario 1.4, but n parameter was fixing at 2 because it was supposed that there is not enough information in the input data to estimate all the parameters of the model, and fixing n the stability of the model would improve.

The model converged and the results obtained were similar to the obtained in scenario 1.4 (Table 5). The intrinsic rate of growth was estimated at 1.14, the same value than in scenario 1.4, and confidence intervals were narrower in this case. Values of r > 1 are supposed to be very high for a gadidae species as pollack but the results obtained could be considered realistic. The reference points were MSY = 1962 t corresponding to a B_{MSY} = 3498 t. The perception of the stock in 2019, was that the biomass was above the reference point, and the fishing mortality was below F_{MSY}. Since 2006, biomass has been above B_{MSY} and fishing mortality below F_{MSY} (Figure 7). The diagnostics only failed for normality of catch residuals with a p-value=0.02 for the Shapiro test (Figure 8). The retrospective analysis is presented in Figure 9.

Only Retros -1, -2 and -3 converged and the B and F trajectories were inside the 95% credible intervals of the base run.

Table 5. Scenario 4. Estimates and 95% confidence intervals of model parameters. Reference points and current states.

Model Parameters

	estimate	**cilow**	**ciupp**
alpha	0.82	0.26	2.62
beta	1.20	0.24	5.94
r	1.14	0.69	1.89
rc	1.14	0.69	1.89
rold	1.14	0.69	1.89
m	2088	1660	2625
K	7302	4582	11638
q	2.93E-05	1.62E-05	5.31E-05
n	2.00	2.00	2.00
sdb	0.22	0.10	0.51
sdf	0.10	0.03	0.32
sdi	0.18	0.09	0.35
sdc	0.12	0.05	0.27

Reference Points (s)

	estimate	cilow	ciupp
Bmsys	3498	2153	5683
Fmsys	0.56	0.34	0.93
MSYs	1962	1546	2491

States (s)	estimate	cilow	ciupp
B_2019.94	4635	2480	8664
F_2019.94	0.35	0.19	0.67
B_2019.94/Bmsy	1.33	0.88	2
F_2019.94/Fmsy	0.63	0.38	1.05

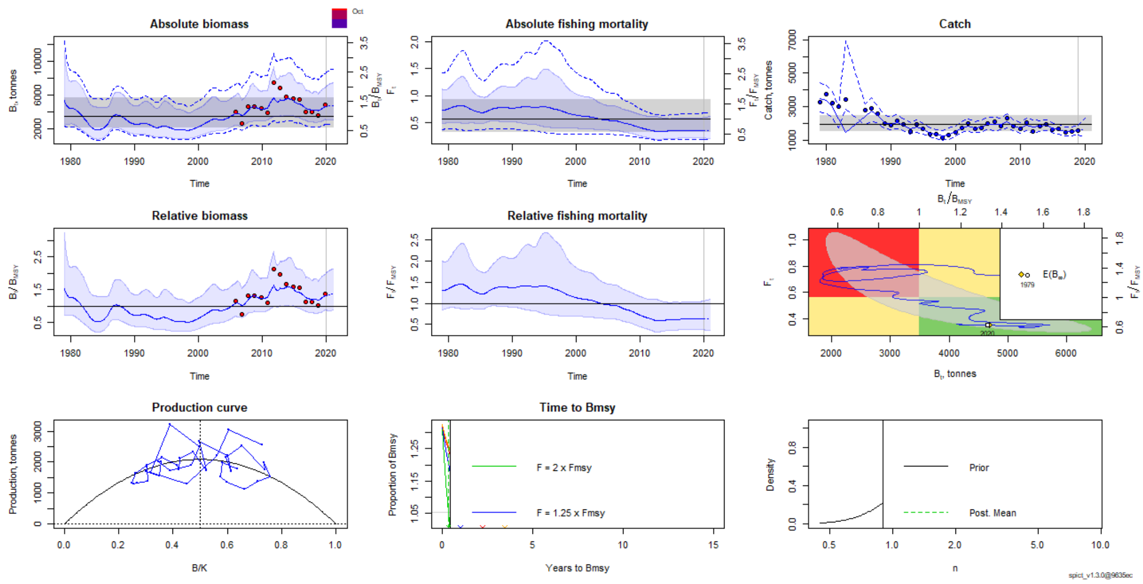

Figure 7. Scenario 1.5. Results of model fit.

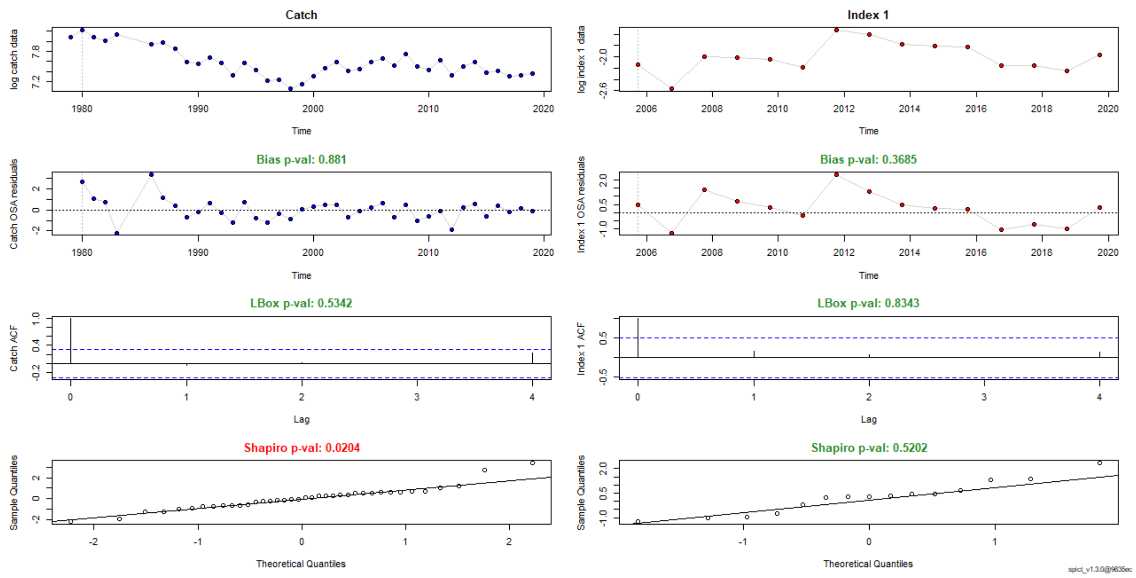

Figure 8. Scenario 1.5. Model diagnostics.

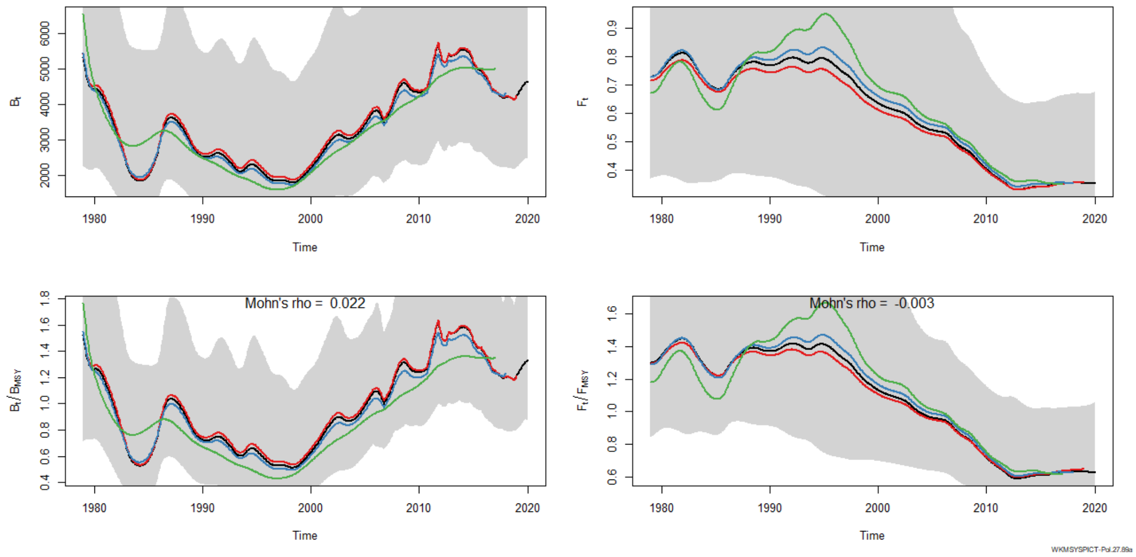

Figure 9. Scenario 1.5. Retrospective analysis for 3 peels. Estimates of biomass and fishing mortality, and their respective relative values, with 95% confidence regions. Mohn's rho number is indicated for relative quantities of biomass and fishing mortality. Retro -4 and Retro -5, not shown in the plot, did not converge.

 # Scenario 1.6. The model configuration included fixing n=2 and priors used for r were: logr <- c(log(0.23), 0.26) based on SPMpriors results. The model did not converge.

Scenarios 2

 # Scenario 2.1. This scenario was configured with the default settings of SPiCT. The model converged and diagnostics were right, but retrospective did not converge (any Retro). The absolute and relative estimates of F and B show really wide intervals of confidence. Results indicated that the biomass was above B_{MSY} through the time series and F was always below F_{MSY}.

 # Scenario 2.2. This scenario was configured with the default settings of SPiCT and fixing n=2. The model did not achieve the convergence.

 # Scenario 2.3. This scenario was parameterized with the default settings of SPiCT, fixing n=2 and setting priors for bkfrac=c(log(0.5),0.2). The model converged and diagnostics were right. In the retrospective analysis: trajectories B and F were inside the 95% credible intervals of the base run but the Mohn's rho > 0.2. Model was sensitive to the change of the starting values of parameters.

 # Scenario 2.4. This scenario was configured with the default settings of SPiCT, fixing n=2, setting priors for bkfrac=c(log(0.5),0.2) and priors for log r= c(log(0,23), 0,26) The model converged and diagnostics were right. The retrospective analysis: trajectories for relative B and F were inside the 95% credible intervals of the base run, but the Mohn's rho > 0.2. Model was sensitive to the change of starting values of parameters.

Table 6. Comparision of results from scenarios that achieved the convergence.

Model Parameters	Scenario 1.4	Scenario 1.5	Scenario 2.1	Scenario 2.3	Scenario 2.4
alpha	0.82	0.82	3.83	3.36	3.06
beta	1.2	1.20	1.15	1.49	1.84
r	1.14	1.14	0.13	0.15	0.22
m	2088	2088	2147	2108	2213
K	7316	7302	50802	55080	40077
q	2.92E-05	2.93E-05	4.22E-06	7.04E-06	1.10E-05
n	2	2.00	1.19	2	2
sdb	0.22	0.22	0.06	0.07	0.08
sdf	0.1	0.10	0.08	0.06	0.05
sdi	0.18	0.18	0.24	0.24	0.25
sdc	0.12	0.12	0.09	0.09	0.10
Reference Points (s)					
Bmsys	3510	3498	20169	27036	19710
Fmsys	0.56	0.56	0.11	0.08	0
MSYs	1963	1962	2121	2034	2145
States (s)					
B_2019.94	4651	4635	31387	18726	11869
F_2019.94	0.35	0.35	0.05	0.08	0.13
B_2019.94/Bmsy	1.32	1.33	1.56	0.69	0.6
F_2019.94/Fmsy	0.63	0.63	0.47	1.11	1.22

4. Conclusion

The scenario 1.4, assuming priors for logn (Thorson et al. 2012, gadiformes) and informative priors for r, presented acceptable diagnostics and retrospective. However, model diagnostics indicated a slight deviation of the normality in catch residuals that probably is related with the uncertainty of some catch observations. The retrospective was considered acceptable, although the retro -5 did not converge. It must be highlighted that the model is sensitive to r priors distribution, and the estimate value of r was extremely high for this stock. Besides, the r value (1.14) differs from the one estimated based on life-history parameters of the species and exploitation characteristics of the stock. This model indicates that in 2019 the stock was within safe biological limits. A MSY of 1963 t was estimated for this stock.

5. References

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